EVAPORATION DUCT HEIGHT CALCULATIONS USING EXPERIMENTAL RADIOSONDE CONFIGURATION TO COLLECT NEAR SURFACE HUMIDITY, TEMPERATURE, AND PRESSURE DATA.

LT Aaron D. Lana
Naval Postgraduate School
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Introduction

The subject of evaporation ducts and the ability to quantify their existence is a difficult problem faced by the meteorological community as a whole. Theoretically they can be defined and with a great deal of effort in a research mode they can be observed. However, this is even a difficult task under even the most ideal of cases. There is a significant level of accuracy that is required to make these observations, and such problems as rough seas, ship interference, and accuracy of instrumentation compile the difficulty of this problem.

Having laid out the concerns facing this problem, I attempted to make measurements during a recent cruise for Operational Oceanography at the Naval Postgraduate School. The cruise took place from January 24, 2004 through February 2, 2004. Figure (1) is the ship track and data acquisition locations. The data I was concerned with was the navy blue diamonds, which are the kite data collected in the surface layer. The data from the two previous cruises which had kite data were added to the figure and are represented by the red arrows. The arrows illustrate the site and number of set of data collected at that location (if multiple set were collected).

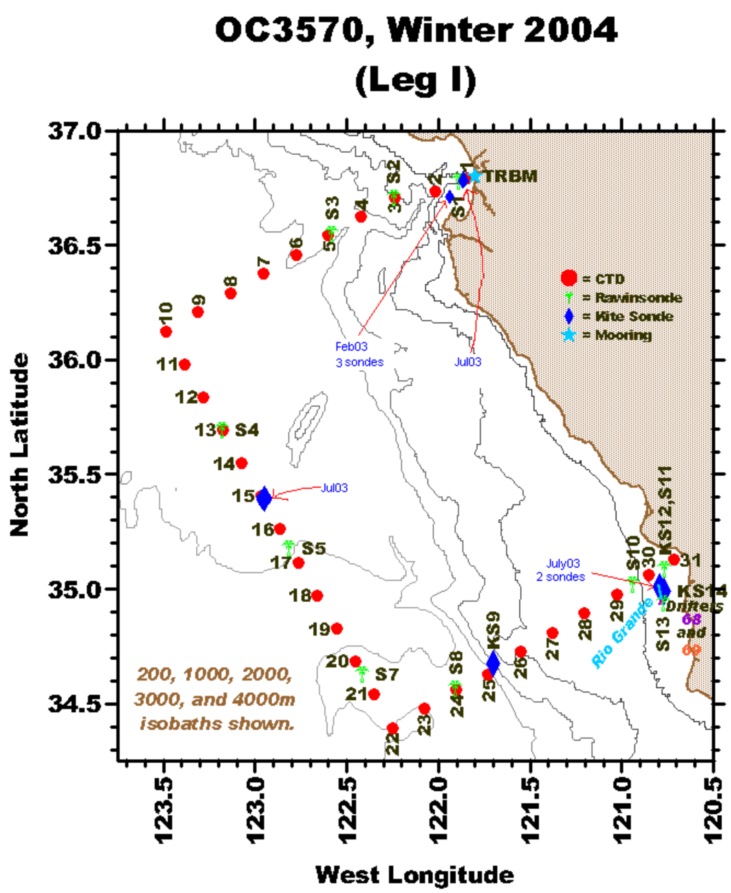

Figure 1. Cruise track and data collection locations.

As mentioned previously I used data collected (using the same method as this cruise) from two previous Operational Oceanography cruises. One was from the July 2003 cruise and the other from the February 2003 cruise. The two sets of data increase the probability that there will be observations close enough to the surface to calculate the duct height. In addition it provides a set of data from a similar time, and a period that is significantly different, i.e. summer, to compare.

Understanding Evaporation Ducts

An evaporation duct is a subset of a surface duct. Evaporation ducts form in the lowest few meters of the atmosphere near the surface. The primary influence on the evaporation layer is the profile of humidity. Near the surface the humidity goes to 98% (due in part to the salinity effects) as it interfaces with the ocean surface. Propagation of radar and communications systems are drastically altered based on the strength of this effect. The refractivity (N) which is dependent on the total atmospheric pressure (P), water vapor pressure (e), and temperature (T) is represented by

$$N = (n-1)\times 10^{6} = 77.6\frac{P}{T} - 5.6\frac{e}{T} + 3.75\times 10^{5}\frac{e}{T^{2}} \qquad (1)$$

which does not take into account the curvature of the Earth. To take into account the Earth's curvature we use N, earth's radius in meters (r_e), and altitude (z) to define the modified refractivity (M).

$$M = N + \frac{z}{r_e \times 10^{-6}} = N + 0.1568z \qquad (2)$$

The gradient of the modified refractivity with height is the best method for categorizing the strength of the evaporation duct. To get the evaporation duct height I used the atmospheric data collected during the cruises to calculate M and plot it versus height. The duct height is defined by the minimum M value on the curve.

Data Collection

For this project I used two sources of data to make the calculations required for predicting the evaporation duct height. The key source of data was from a Vaisala RS-80-15L Radiosonde, which collected humidity, temperature, and pressure measurements. I have listed the accuracy of the individual sensors and their lag time in Table 1.

Table 1.

	Sensor Type	Range	Accuracy	Resolution	Response / Lag Time
Pressure (and Height)	Capacitive Aneroid	1060 to 3 hPa	0.5 hPa	0.1 hPa	
Temperature	Capacitive Bead	-90 to 60 °C	0.2 °C	0.2 °C	<2.5 sec
Humidity	Thin Film Capacitor	0 to 100%	2%	1%	1 sec

The second set of data was collected from the array of ship sensors. These files were collected for each day of the cruise. The different parameters such as wind speeds, wind directions, sea surface temperature, radiance, GPS position, humidity, salinity, speed over ground (SOG), course over ground (COG), and most importantly the satellite derived time (GMT). The time is critical for linking the two data sets. These parameters were saved in UDAS text files at 20 second intervals.

Methods

To process the data from a raw state into a usable product the use of Matlab and several custom designed programs produced the end product, a modified refractivity plot. The data from a radiosonde was transmitted to the ship via a carrier frequency, and processed by the shipboard equipment into data files. These files were then appended with the current shipboard observations as a reference. The files were named for their initial time, i.e. 04012920.50z, which were used to adjust the data from the radiosonde to the onboard ship data in the UDAS files.

Matlab could not directly ingest the radiosonde files, so an external Matlab program titled, 'loadsnd_d3_feb2004.m', was employed to read the radiosonde files and create a Matlab data file. This produced a '.mat' file with the same file name as the radiosonde file. The next step was to load this file into Matlab where it was used by the program, 'workingkite_mat_2004.m'. This second program created plots of the radiosonde and ship data together on a shared time line. The unfiltered data had to have an artificial surface added to smooth the changes in surface pressure. To accomplish this, an estimation of height above the water was made during kite operations each time the kite returned close to the surface. In the Matlab program it asked to set the corrected surface in the plot of raw height versus time. In Figure (2) the magenta line below the data represents the corrected surface.

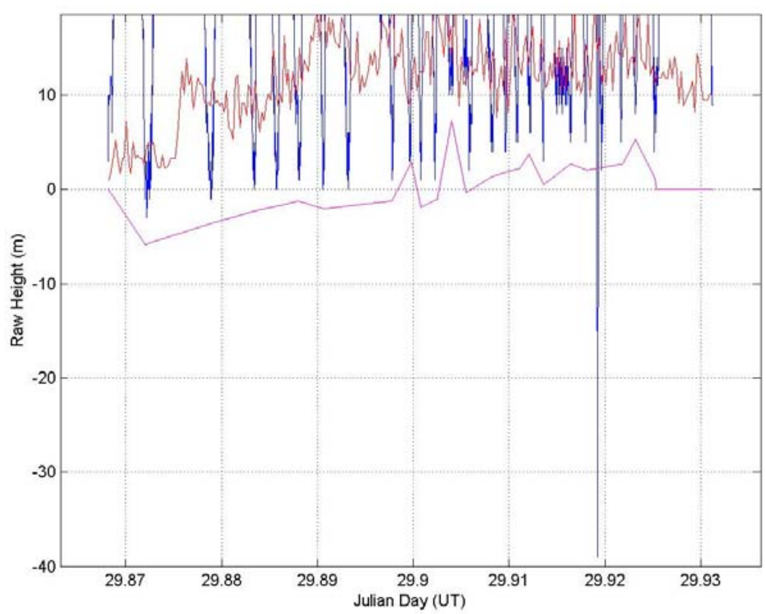

Figure 2. Raw radiosonde data with ship data and corrected surface height. Blue line is radiosonde, magenta is artificial surface, and red is ship surface pressure.

The next step of the program was to create a bad data file and separate it from the usable data. Generally I removed the data at the start and finish of the files to remove the data collected prior to launch and after recovery. Any outliers that were out of the range from normal values were removed. After removing the bad data averaging bins were created to group similar data together. I used the ship's pressure, temperature, and humidity readings to make judgments when a change in the surface conditions warranted a new averaging bin be created. The final step in processing the data was to select air temperature, sea surface temperature, and the relative humidity for each of the averaging segments. The total number of averaging bins was dependent on the consistency of the data. In an ideal case the entire data set would be used, however in most cases the data was broken into several bins per file. This suggested rapid changes in environmental conditions during the data collection.

Results

The majority of the plots of M versus height show that there is not enough data close to the surface to identify a duct. Figure (3) shows a positive slope for M from just above the surface to approximately 100 meters. There is no obvious inflection point for M suggesting a duct. The black lines represent a best fit curve of the data by Matlab, based on the input of T_{air}, T_{sfc}, and RH. In this case is suggested a duct height of 8 m. This is a product of assuming the relative humidity must go to 98% at the surface. In the plot of humidity, the highest relative humidity observed near the surface was only 80%, well below the 98% expected. This illustrates the differences between the collected data and curve fit analysis. The potential temperature plot shows that there is an unstable condition present with colder air temperatures over warmer sea surface temperatures, suggestive of high relative humidity directly above the surface.

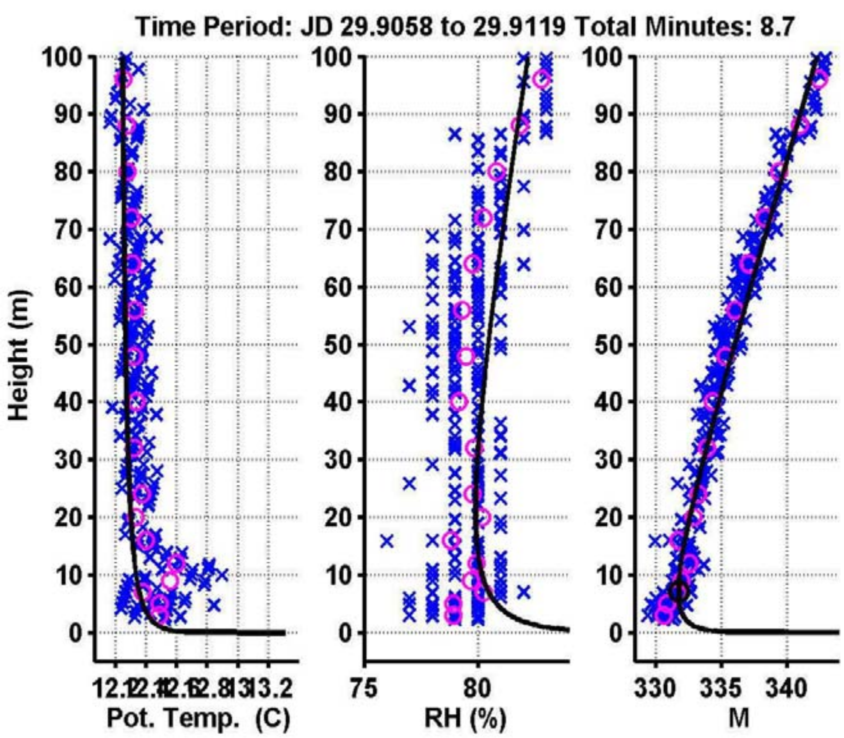

Figure 3. Plot of data with no visible signs of evaporation duct.

On several occasions, such as figure (4), the data plots reflected a possible ducting condition. The relative humidity was slightly greater than 85% and the profile of M showed signs of creating an inflection close to 5 meters. It still lacked the very near surface measurements required to be completely certain, but a definite negative slope is apparent near the surface.

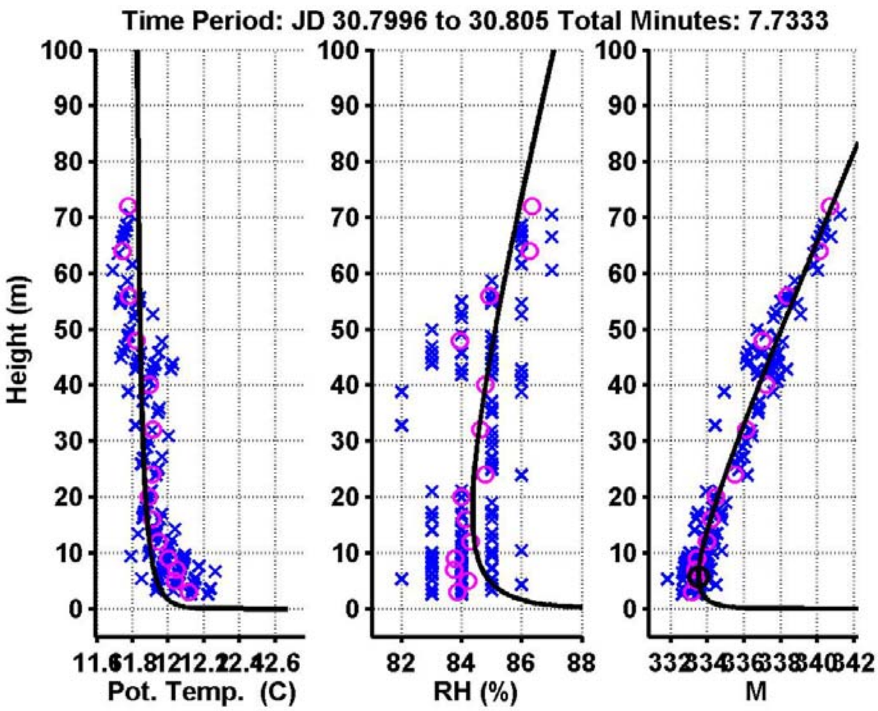

Figure 4. Plot of possible evaporation duct near surface.

Conclusion

The processed data reflected a wide variation in temporal, spatial, and environmental characteristics. The impact from the sea state created by these conditions hindered the collection of data close enough to the surface to resolve the evaporation duct.

The kite method is an effective method for making measurements away from the ship, eliminating the ship's signature in the data. The shortcoming of this technique however has made finding the evaporation duct height difficult. Due in part to the difficulty of operating the kite and getting it within the lower few meters of the surface, the radiosonde is unable to collect the critically important humidity data close to the surface. On the rare occasion that the kite would get the instrument package within one meter, the amount of time it was near the surface was not long enough to get a good data value. The lag time for the humidity sensor is one second from Table (1). Rarely was the kite operator able to maintain the kite's height within the lower one meter range for more than a fraction of a second, due to the kite's unstable flight characteristics. This is reflected in the data for the maximum relative humidity and it being only 85%. This value is considered too low for the surface, and suggests that the kite was not getting the instrument close enough to calculate an accurate evaporation duct height.

References

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